

Age, Growth and Mortality of *Tylochromis jentinki* (Steindachner, 1895) in Ebrié Lagoon, Ivory Coast

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Abstract— Monthly data of length composition for *Tylochromis jentinki* (Steindachner, 1895), landed between February 2004 and January 2006 in Ebrié Lagoon (Ivory Coast) were used to estimate the growth, mortality and exploitation parameters of the stock. A total of 1850 individuals ranging from 7.5 to 23.5 cm SL (standard length), were examined. Length frequency data were analyzed with FiSAT software using the ELEFAN 1 package to estimate the population parameters. We estimated von Bertalanffy growth parameters: $L_{\infty} = 25.00$ cm, $K = 0.67$ year⁻¹, and $t_0 = -0.28$ year⁻¹, with the growth performance index, ϕ' of 2.62. The length-weight relationship was $W = 0.0215 \times SL^{2.98}$ and described isometric growth for the species with an asymptotic weight (W_{∞}) = 314.99 g. Total mortality (Z) estimated from catch-curve analyses was = 2.38 year⁻¹. Natural mortality based on growth parameters and mean environmental temperature ($T = 28^{\circ}\text{C}$) was $M = 1.45$ year⁻¹. Furthermore, the fishing mortality rate of 0.93 year⁻¹ was by far in excess of the precautionary target ($F_{opt} = 0.73$ year⁻¹) and slightly under the limit ($F_{limit} = 0.97$ year⁻¹) biological reference points. With this level of mortality and exploitation level ($E = 0.39 < 0.50$), the stock was under-exploited.

Keywords— Age, growth, Cichlidae, exploitation, recruitment, length frequency.

I. INTRODUCTION

Age determination and the estimation of age associated parameters such as growth rate, natural mortality and longevity are important for assessment and fisheries management decisions (Campana, 2001; Dulcic et al., 2007). There are several methods of modelling fish growth (Ricker, 1975). However, the von Bertalanffy (1938) growth function is by far the most studied and widely applied of all length-age models in fish biology (Santamaria et al., 2009). A variety of methods have been used to determine age, usually based either on the size analyses of caught individuals or interpretation of the discontinuities of hard structures of the fish (Santamaria et al., 2009). The reading of hard parts, such as otoliths, scales, spines and vertebrae, is based on number annuli, which are interpreted as periodic events (Leonardos and Tsikliras, 2011). In many species, otoliths and scales have often been chosen for growth studies because they are easy to sample and have obvious and well-defined growth marks; depending on the morphology and biology of the species (Leonardos and Tsikliras, 2011). When skeletal structures are used to age fish, a validation method with a twofold importance is a necessary prerequisite (Bagenal and Tesch, 1978). First, the growth of the skeletal structure should be proportional to the size of the fish, and the periodicity such as daily, lunar, monthly, annual and constancy of growth mark formation is required (Campana and Neilson, 1985). Age can be determined indirectly using length-frequency distribution (Sparre et al., 1989). Several methods have been used for age and growth determinations. Of these, the Electronic Length Frequency Analysis (ELEFAN) routine implemented in the Food and Agriculture Organization-International Centre for Living Aquatic Resource Management (FAO-ICLARM) Stock Assessment Tools (FiSAT) software has been most frequently used for estimating population parameters of finfish and shellfish, primarily because it requires only length-frequency data (Al-Barwani et al., 2007). The FiSAT method has been widely applied in growth studies, especially in tropical and subtropical countries (Tah et al., 2010). Fish stock assessment should be carried out for each stock separately, since an essential characteristic of a stock is that its population parameters remain constant throughout its area of distribution (Wang and Liu, 2006).

The Cichlid, *Tylochromis jentinki* is endemic to western Africa and is distributed from Gambia to Ghana (Paugy et al., 2003). This species is important ecologically and commercially, and is widely exploited and cultured. Populations in the Ebrié Lagoon have been declining due to high mortalities arising from water pollution and fishing pressure. *T. jentinki* is one of the most important fishery resources for the Ivorian artisanal fisheries (Amon-Kothias, 1982; Konan et al., 2011). The species is inexpensive and easily affordable by the low-income segment of the population. Despite its wide distribution and economic importance, few studies on *T. jentinki* have been conducted; research has generally focused on food habits and reproduction (Atsé et al., 2009; Konan et al., 2011). Age and growth data is lacking, and the age determination of the species has never been evaluated. The aim of this study was to estimate the population parameters and exploitation level of *T. jentinki* from Ebrié Lagoon.

II. MATERIALS AND METHODS

We collected a total of 1850 *Tylochromis jentinki* from Ebrié Lagoon (Fig. 1), by sampling monthly between February 2004 and January 2006, using multi-meshed nylon gillnets (10-50 mm mesh sizes). Water temperatures and salinities were recorded on each sampling date. For each specimen, standard length (SL, 0.1 cm) and total weight (W, 0.01g) were measured.

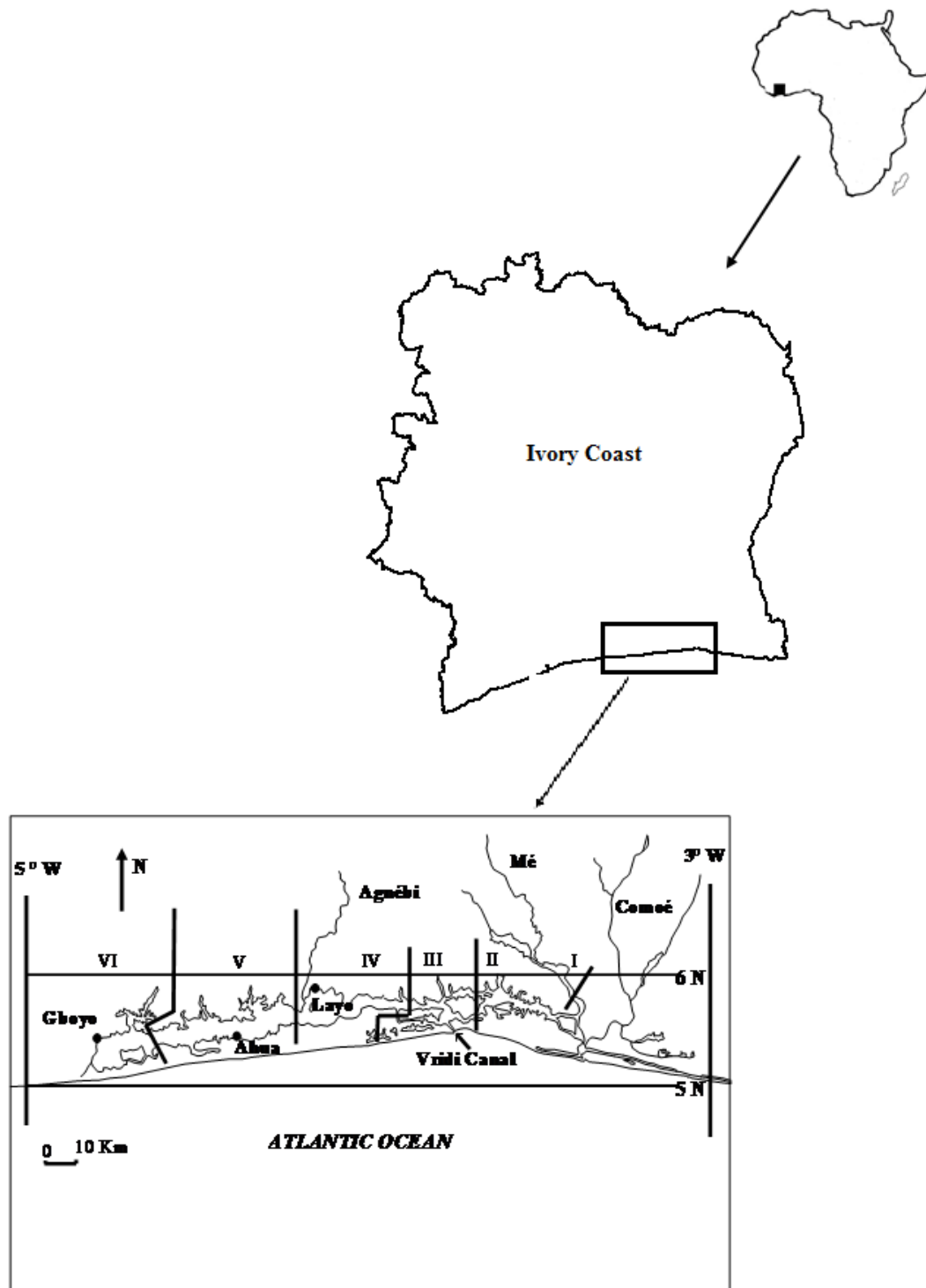


FIG. 1 MAP OF EBRIÉ LAGOON (LABELS I TO VI SHOWING SECTORS) AND DIFFERENT SAMPLING SITES (●).

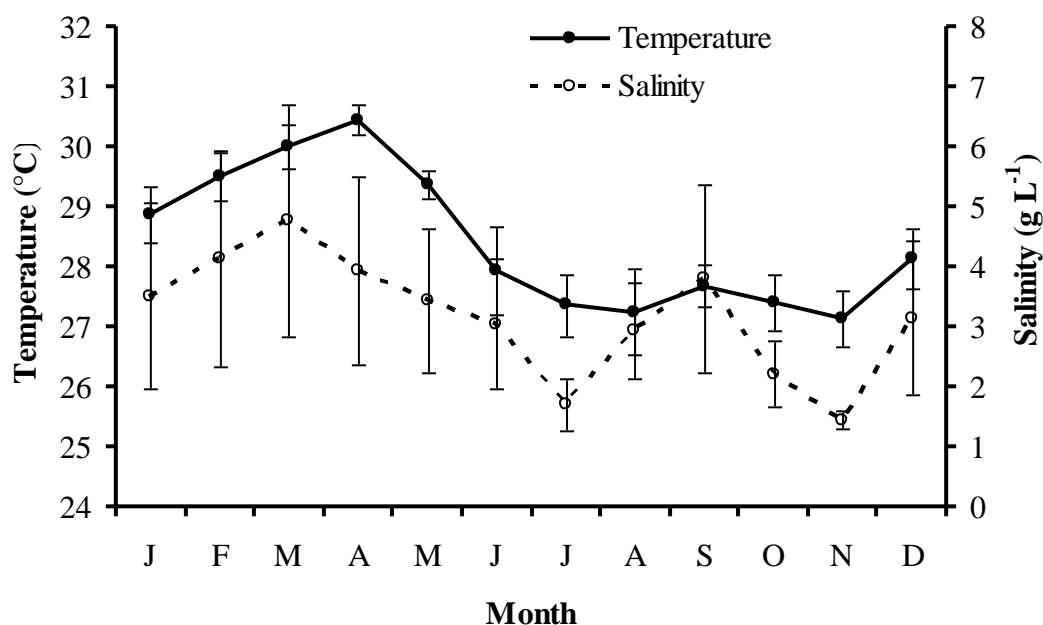


FIG. 2 MONTHLY TEMPERATURE AND SALINITY VARIATIONS FROM FEBRUARY 2004 TO JANUARY 2006 IN EBRIÉ LAGOON.

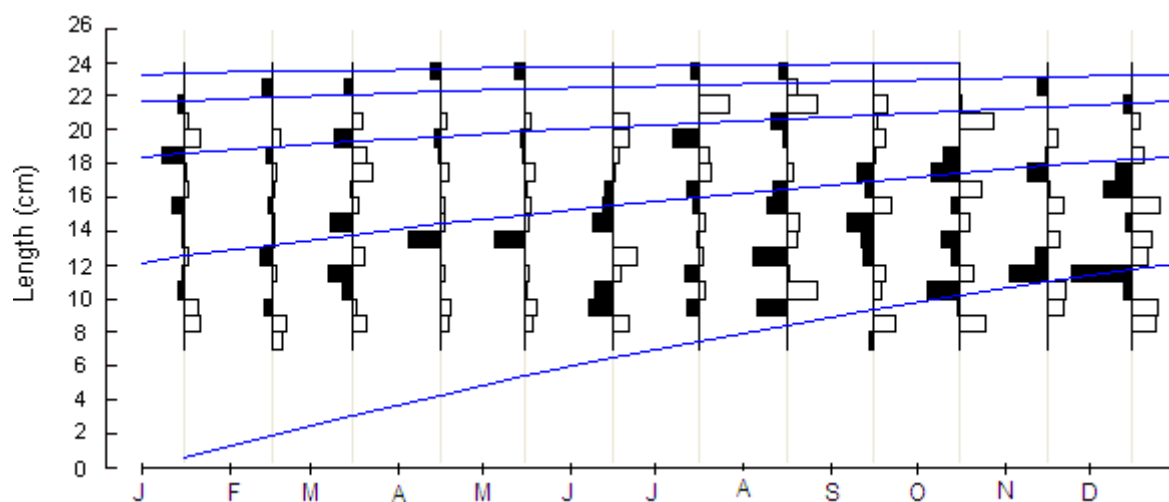


FIG. 5 LENGTH-FREQUENCY DISTRIBUTION OUTPUT FROM FISAT WITH SUPERIMPOSED GROWTH CURVE FOR TYLOCHROMIS JENTINKI FROM EBRIÉ LAGOON. BLACK AND WHITE BARS = POSITION AND NEGATIVE DEVIATION FROM 'WEIGHED' MOVING AVERAGE OF THREE LENGTH CLASSES REPRESENTING PSEUDO-COHORTS.

The data in length and weight of individuals were used to estimate the length-weight relationship using the formula (Le Cren 1951).

$$W = aL^b$$

Where, W is the weight (g), L is the total length (cm), a is the intercept and b is the slope.

The parameters a and b were estimated by least squares linear regression on log-log transformed data

$$\text{Log}_{10} W = \text{Log}_{10} a + b \text{Log}_{10} L$$

The coefficient of determination (R^2) was used as an indicator of the quality of the linear regression (Quinn and Deriso, 1999). In order to check if the b value was significantly different from 3, the t -test was used at $p = 0.05$.

The data analysis was done using ELEFAN I routine of FAO ICLARM Stock Assessment Tools II (FiSAT II) (Gayanilo et al. 1996). The growth parameters were obtained using the Von Bertalanffy Growth Formula (Sparre and Venema 1998), expressed as:

$$L_t = L_{\infty} \left(1 - e^{-K(t-t_0)} \right)$$

Where L_t is the predicted length (cm) at the time t (year), L_{∞} is asymptotic length or theoretical maximum (cm), K is the body growth coefficient (measuring how fast L_{∞} is attained), and t_0 is the hypothetical time at which the length is equal to zero.

Accuracy of the growth parameters was tested using Munro's growth performance index (Pauly and Munro, 1984):

$$\phi' = \log_{10} K + 2 \log_{10} L_{\infty}$$

The potential longevity or approximate maximum age (t_{\max}) of the species was calculated using Pauly and Munro's formula (1984):

$$t_{\max} = 3/K$$

The instantaneous rate of total mortality (Z) was estimated as the slope of a linear regression of natural log-transformed numbers at age (Ricker, 1975). Natural mortality rate (M) was estimated using Pauly's equation (1980):

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

Where L_{∞} and K are von Bertalanffy parameters, T is the annual mean temperature of the habitat. We use a value of $T = 28.4^{\circ}\text{C}$. Fishing mortality (F) and exploitation rates (E) were then estimated according to Ricker (1975):

$$F = Z - M \text{ and } E = F/Z$$

The exploitation rate indicates whether the stock is lightly ($E < 0.5$) or strongly ($E > 0.5$) exploited, based on the assumption that the fish are optimally exploited when $F = M$ or $E = 0.5$ (Gulland, 1971).

The recruitment pattern was obtained from the estimated growth parameters by backward projection of length-frequency data, as done in ELEFAN 1, onto the time axis (Moreau and Cuende, 1991). This type of back-calculation allows identification of the number of seasonal pulses of recruitment that have been generated by the population represented in the length frequency data (Gayanilo et al., 2002). Input parameters were L_{∞} , K and t_0 .

Relative yield per recruit (Y/R) and biomass per recruit (B/R) were estimated according to the model of Beverton and Holt (1957) using the Knife-edge selection. The resource status was evaluated using estimates of exploitation rate (E) associated with a maximum sustainable yield (E_{\max}) and by comparing estimates of the fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points which were defined as $F_{\text{opt}} = 0.5M$ and $F_{\text{limit}} = 2/3M$ following Patterson (1992).

III. RESULTS

Water temperatures ranged from 27.1°C (November) to 30.5°C (April) with a mean of $28.4 \pm 1.2^{\circ}\text{C}$. No differences in temperature profiles were found among sampling sites (ANOVA, $p < 0.05$) in Ebrié Lagoon (Fig. 2). The mean value of the salinity was 3.2 ± 1.5 ppt (mean \pm SD), with the lowest value of 1.5 ppt during November and the highest value (4.2 ppt) in February.

Fish sampled ($n = 1850$) ranged in size and body weight ranging from 7.5 to 23.5 cm (SL) and from 11.90 to 407.57 g. The majority (76.04%) of specimens were between 100-180 mm (SL). The monthly length-frequency data are shown in Figure 3. The length-weight relationship for *T. jentinki* was

$$W = 2.15 \times 10^{-2} \times \text{SL}^{2.98} \quad (R^2 = 0.89; n = 1850; p < 0.05).$$

The computed growth coefficient (b) 2.98 was not statistically different from 3 (t -test; $P > 0.05$). Observed length-weight data is plotted in Fig. 4.

Figure 5 shows the growth curves generated from ELEFAN 1 during the courses of this study. The estimated growth parameters (L_{∞} , K , and t_0) and derived growth performance index (ϕ') are given in Table 1. The asymptotic length (L_{∞}), the growth coefficient (K), and the theoretical age at length zero (t_0) year⁻¹ for *T. jentinki* were respectively 25.00 cm, 0.67 year⁻¹, and -0.28 year⁻¹. From these results, the growth performance index (ϕ') was 2.62 while longevity (t_{max}) was 4.48 years. The length range obtained in the fishery was 6-24 cm. In addition, the length range which contributed significantly to the fishery was 8-18 cm.

TABLE 1.
POPULATION PARAMETERS OF TYLOCHROMIS JENTINKI FROM EBRIÉ LAGOON.

Population parameters	Values
Asymptotic length (L_{∞}) in cm	25.00
Growth coefficient (K) in year ⁻¹	0.67
Hypothetical age (t_0) in year ⁻¹	-0.28
Longevity (AGE_{max}) in year	4.48
Growth performance index (ϕ')	2.62
Natural mortality (M) year ⁻¹	1.45
Fishing mortality (F) year ⁻¹	0.93
Total mortality (Z) year ⁻¹	2.38
Exploitation rate (E)	0.39
Allowable limit of exploitation (E_{max})	0.42
Length at first capture (L_c) in cm	8.09
Length range in cm	6-24
Sample number (N)	1850

The catch-curve based estimate of instantaneous total mortality (Z) for *T. jentinki* was 2.38 year⁻¹ (Fig. 7). Natural mortality (M) was 1.45 year⁻¹ and fishing mortality (F) 0.93 was year⁻¹. The exploitation level (E) of *T. jentinki* was 0.39. The recruitment pattern was bimodal with two major peaks of recruitment for *T. jentinki*. The first peak occurred in February-May and the second peak was observed in September-October (Fig. 8).

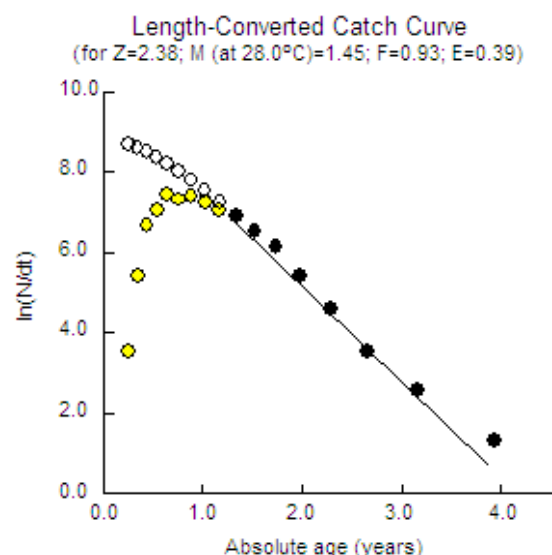


FIG. 7 LENGTH-CONVERTED CATCH CURVE FOR TYLOCHROMIS JENTINKI FROM EBRIÉ LAGOON, IVORY COAST. SOLID DOTS ARE THOSE USED IN CALCULATING THE PARAMETERS OF THE STRAIGHT LINE, THE SLOPE OF WHICH IS AN ESTIMATE OF Z . OPEN DOTS REPRESENT FISH NOT FULLY SELECTED BY THE GEAR USED IN THE FISHERY AND/OR NOT USED IN MORTALITY ESTIMATION.

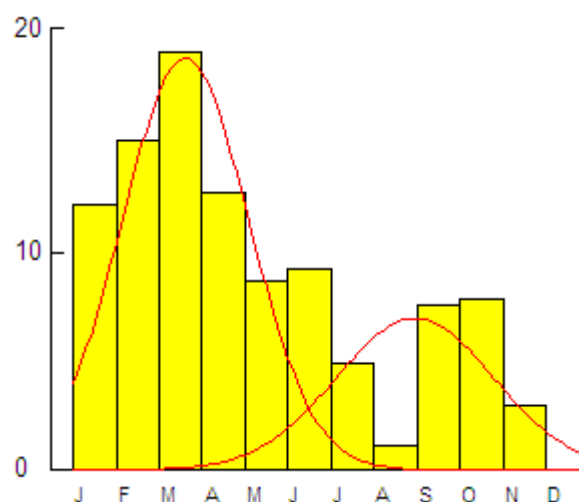


FIG. 8 RECRUITMENT PATTERN OF TYLOCHROMIS JENTINKI FROM EBRIÉ LAGOON, IVORY COAST SHOWING TWO RECRUITMENT PULSES (ONE MAJOR AND ONE MINOR) WITHIN A YEAR.

The relative Y/R and B/R analysis of *T. jentinki* were computed using the Beverton and Holt (1957) knife-edge procedure. The computed maximum allowable limit of exploitation (E_{max}) for the Y/R and B/R was 0.56 (Fig. 9).

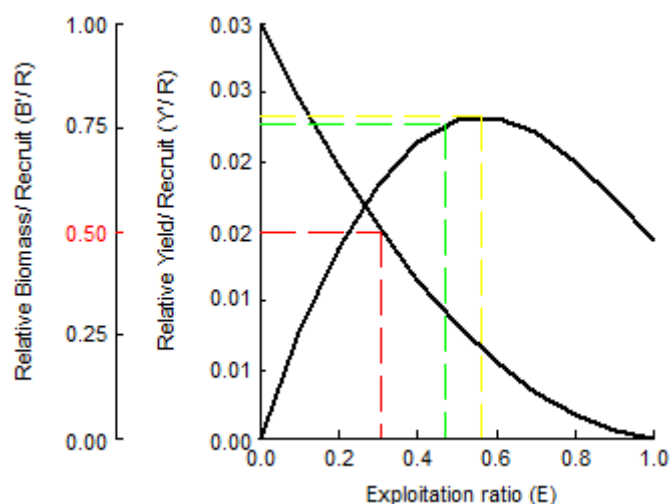


FIG. 9 RELATIVE YIELD-PER-RECRUIT (Y/R) AND BIOMASS-PER-RECRUIT (B/R) CURVES FOR TYLOCHROMIS JENTINKI FROM EBRIÉ LAGOON USING THE SELECTION GIVE OPTION

IV. DISCUSSION

The slope (b) value of the length-weight relationship calculated for the overall sample of *T. jentinki* was 2.98 and is not significantly different from 3; this indicates isometric growth (Quinn and Deriso, 1999). The available data analysis in the literature shows that the value of b for tropical fish populations can vary from 2.49 to 3.86 (Carlander, 1977; Pauly, 1979). Geographic location or environmental conditions, food availability, longevity and growth rate, sex, age, sexual maturity, and disease and parasite loads can affect the length-weight relationship (Ricker, 1975; Pompei et al., 2011).

Estimated asymptotic length ($L_{\infty} = 25.00$ cm) reported in this study was greater than the Gambia estuary population (20.58 cm) (Villanueva, 2004). On the other hand, our K value of 0.67 year⁻¹ was lower than both values reported in the literature for populations of Gambia estuary ($K = 0.95$ year⁻¹) (Villanueva, 2004) and Taia River ($K = 0.72$ year⁻¹) in Sierra Leone (Payne and McCarton, 1985). Differences in von Bertalanffy growth parameters for these different studies may be attributed to temporal and geographical variations. Fish populations of the same species from different geographical regions may exhibit highly variable, individual growth rates (Wootton, 1998). The differences may be due to the differences in stock

population emanating from genetic factors, environmental variables of their aquatic habitat (Odo and Inyang, 2001), nutrient availability or population dependent factors of the particular geographical location (Francis and Sikoki, 2007).

On the whole, growth performance index ($\phi' = 2.62$) of *T. jentinki* estimated by means of FiSAT software package was closely similar to those estimated by Moreau et al. (1986) for African lacustrine populations of *Oreochromis mossambicus* (ranged between 2.05 and 2.80) and *Oreochromis niloticus* (2.41-3.11), suggesting a similar growth pattern across different population. According to Baijot and Moreau (1997), the ϕ' mean values for some important fishes in Africa range of 2.65-3.32, indicated that the growth rate of *T. jentinki* was low in Ebrié Lagoon.

Gulland (1971) suggested that in an optimally exploited stock, fishing mortality (F) should be equal to natural mortality (M), resulting in an exploitation ratio of 0.5. In this study, the higher natural mortality ($M = 1.45 \text{ year}^{-1}$) compared to fishing mortality ($F = 0.93 \text{ year}^{-1}$) indicates the unbalanced position of the *T. jentinki* stock in the Ebrié Lagoon. This can be due to the fact of some predators. In fact, several predators include *Citharichthys stampflii* and *Elops lacerta*, preyed on juveniles and small ($< 2 \text{ cm TL}$) while *Sphyearaena piscatorum* and *Polynemus quadrifilis* preyed on adult *T. jentinki* (Amon-Kothias, 1982). In addition, this result may be due to the high levels of pollution in Ebrié Lagoon. For an optimally exploited stock, natural and fishing mortalities should be equal or $E = 0.5$ (Gulland, 1971). The maximum exploitation rate (E_{\max}), which gives maximum relative yield per recruit, is estimated at 0.56 and differs from the exploitation rate (0.39) estimated in this study. The specified precautionary target reference point (F_{opt}) and limit reference point (F_{limit}) values were also used to evaluate the status of the stock. The fishing mortality was above the F_{opt} (0.73 year^{-1}) but slightly below the F_{limit} (0.97 year^{-1}), suggesting that the stock is under exploited.

This study elucidate that the recruitment pattern of *T. jentinki* is continuous with two recruitment peaks; one major and one minor recruitment peak per year (Figure 5). This is consistent with Pauly's (1982) assertion of double recruitment pulses per year for tropical fish species and for short-lived species. There are no published reports on *T. jentinki* recruitment in Ivory Coast. However, it has been reported that this species spawns mainly from October to December, and again in April (Atsé et al., 2009). We think that the major recruitment peak (February-May) observed in this study corresponds to the former spawning season. The spawning is initiated by a decrease in water temperature from 30.7 to 30.1 °C (March-April) and from 29.0 to 27.2 °C (September-November). Reduced temperature and salinity, associated with the rainy season (April) and flooding (October-November) are stimuli which would initiate spawning, as was reported in this species (Atsé et al., 2009).

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REFERENCES

- [1] Al-Barwani, S.M., Arshad, A., Amin, S.M.N., Japar, S.B., Siraj, S.S. and Yap, C. K. 2007. Population dynamics of the green mussel *Perna viridis* from the high spat-fall coastal water of Malacca, Peninsular Malaysia. *Fisheries Research*, 84: 147-152.
- [2] Amon-Kothias, J.B. 1982. Biologie, écologie et pêche de *Tylochromis jentinki jentinki* (Cichlidae) en lagune Ebrié (Côte d'Ivoire). Thèse de 3ème cycle, Université de Bretagne Occidentale.
- [3] Atsé, B.C., Konan, K.J., Kouassi, N.J. 2009. Biologie de la reproduction du Cichlidae *Tylochromis jentinki* (Steindachner, 1895) dans la lagune Ebrié (Côte d'Ivoire). *Cybiu*, 33(1): 11-19.
- [4] Bagenal, T.B. and Tesch, F.W. 1978. Age and growth. In: *Methods for Assessment of Fish Production in Fresh Waters* Bagenal, T. B., Ed. Blackwell Scientific Publications, Oxford, UK, pp. 101-136.
- [5] Baijot, E. and Moreau, J. 1997. Biology and demographic status of the main fish species in the reservoirs of Burkina Faso. In: *Hydrological aspects of fisheries in small reservoirs in the Sahel Region*, Technical Centre for Agricultural and Rural Cooperation, Baijot, E. Moreau, J. Barry J. and Bouda S., Eds. Commission of the European Communities, Wageningen, Netherlands, pp. 79-109.
- [6] Beverton, R.J.H. and Holt S.J. 1957. On the dynamics of exploited fish populations. Ministry of Agriculture, Fisheries and Food, Fisheries Investigations, London, 533 pp.
- [7] Campana, S. E. 2001. Review: accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology*, 59: 197-242.
- [8] Campana, S.E., Neilson, J.D. 1985. Microstructure of fish otoliths. *Canadian Journal of Fisheries and Aquatic Sciences*, 42: 1014-1032.
- [9] Carlander, K. 1977. *Handbook of Freshwater Fishery Biology*. The Iowa State University Press, Ames, IA, 431 pp.
- [10] Dulcic, J., Matic-Skoko S., Paladin, A. and Kraljevic, M. 2007. Age, growth, and mortality of brown comber, *Serranus hepatus* (Linnaeus, 1758) (Pisces: Serranidae), in the eastern Adriatic (Croatian coast). *Journal of Applied Ichthyology*, 23(2): 195-197.
- [11] Francis, A. and Sikoki, F.D. 2007. Growth coefficient of fish species within the Andoni River, Niger Delta, Nigeria and their aquaculture implications. *Journal of Fisheries International*, 2(1): 22-26.
- [12] Gayanilo, Jr F.C., Sparre, P. and Pauly, D. 1996. FAO – ICLARM stock assessment tools (FiSAT) user's manual. FAO Computerized Information Series (Fisheries) 8:126.

- [13] Gayanilo, JrF.C., Sparre, P. and Pauly, D. 2002. The FAO-ICLARM Stock Assessment Tools II (FiSAT II) User's guide. FAO, Rome. Available at: <http://www.fao.org/fi/statist/fisoft/fisat/index.htm> (accessed 16 January 2011).
- [14] Gulland, J.A. 1971. The fish resources of the oceans. West by fleet survey. Fishing News (Books) Ltd., for FAO, 255pp.
- [15] Konan, K.J., Atsé, B.C. and Kouassi, N.J. 2011. Food consumption rates in relation to reproduction in *Tylochromis jentinki* (Teleostei: Cichlidae) in Ebrié Lagoon, Ivory Coast. *African Journal of Aquatic Science* 36(1): 11-16.
- [16] Leonardos, I.D. and Tsikliras, A.C. 2011. Validating annulus formation and examining the potential use of pectoral spines for age determination in Aristotle's catfish (*Silurus aristotelis*). *Journal of Applied Ichthyology*, 27: 53-58.
- [17] Moreau, J. and Cuende, F.X. 1991. On improving the resolution of the recruitment patterns of fishes. *ICLARM Fishbyte* 9: 45-46.
- [18] Moreau, J., Bamboni, C. and Pauly, D. 1986. Indices of overall growth performance of 100 tilapia (Cichlidae) populations. In: The first Asian fisheries forum. In: J.L. Maclean, L.B. Dizon and L.V. Hosillos Eds. Asian Fisheries Society, Manila, Philippines, pp. 201-206.
- [19] Odo, G.E. and Inyang, N.M. 2001. Growth, feed utilization and survival of African Catfish, *Clarias gariepinus* (Burhill, 1822). Fingerlings reared in tanks at different salinity levels. *Journal of Aquatic Sciences*, 16: 127-131.
- [20] Pauly, D. 1979. Theory and management of tropical multispecies stocks: a review with emphasis on the Southeast Asian demersal fisheries. *ICLARM Studies Reviews*, 35 pp.
- [21] Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stock. *Journal of CIEM*, 39(3): 175-192.
- [22] Pauly, D. 1982. Studying single-species dynamics in a tropical multi-species context. In: Theory and Management of Tropical Fisheries, Pauly, D. Murphy, G.I., Eds. *ICLARM Fishbyte*, 3: 13-14.
- [23] Pauly, D. and Caddy, J.F., 1985. A modification of Bhattacharya's method for the analysis of mixtures of normal distributions. FAO, Rome, FAO Fisheries Circular 781, 16 pp.
- [24] Pauly, D. and Munro, J.L. 1984. Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte* 2, 21 pp.
- [25] Paugy, D., Lévêque, C. and Teugels, G.G. 2003. Faunes des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest, Tome II. IRD, 814 pp.
- [26] Payne, A.I. and McCarton, B. 1985. Estimation of population parameters and their application to the development of fishery management models in two African rivers. *Journal of Fish Biology*, 27: 263-277.
- [27] Pompei, L., Carosi, A., Pedicillo, G., Rocchini, E. and Lorenzoni, M. 2011. Age and growth analysis of the chub, *Squalius squalus* (Bonaparte, 1837), in the Assino Creek (Umbria, Italy). *Knowledge and Management of Aquatic Ecosystems*, 400 :1-9.
- [28] Quinn, T.I.I. and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York, 542 p.
- [29] Ricker W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, 191: 382.
- [30] Santamaria, N., Bello, G., Corriero, A., Deflorio, M., Vassallo-Agius, R., Bök, T. and De Metrio, G. 2009. Age and growth of Atlantic bluefin tuna, *Thunnus thynnus* (Osteichthyes: Thunnidae), in the Mediterranean Sea. *Journal of Applied Ichthyology*, 25: 38-45.
- [31] Sparre P., Ursin E. and Venema S.C. 1989. Introduction to tropical fish stock assessment. Part 1: FAO Fisheries Technical Paper, 306(1): 1-337.
- [32] Sparre, P. and Venema, S.C. 1998: Introduction to tropical fish stock assessment - Part 1: manual, 306 / 1, Rev. 2. FAO Fisheries Technical Paper, Rome, 465pp.
- [33] Tah, L., Joanny, T.G., N'Douba, V., Kouassi, J.N. and Moreau, J. 2010. Preliminary estimates of the population parameters of major fish species in Lake Ayamé I (Bia basin; Côte d'Ivoire). *Journal of Applied Ichthyology*, 26: 57-63.
- [34] Villanueva, M.C.S. 2004. Biodiversité et relations trophiques dans quelques milieux estuariens et lagunaires de l'Afrique de l'ouest: Adaptations aux pressions environnementales. Thèse de Doctorat. Institut National Polytechnique de Toulouse, 219 p.
- [35] Wang, Y. and Liu, L. 2006. Estimation of natural mortality using statistical analysis of fisheries catch-at-age data. *Fisheries Research*, 78: 342-351.
- [36] Wootton, R.J. 1998. Ecology of teleost fishes. 2nd edition. Kluwer Academic Publisher, London, 386 pp.